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SOUND ATTENUATION CHARACTERISTICS OF THE ARMY APH-5 HELMET

By

Robert T. Camp, Jr., DAC
and
Robert L. Keiser, Sp-4

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U. S. ARMY AEROMEDICAL RESEARCH UNIT
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ABSTRACT

An evaluation of the real-ear sound attenuation characteristics of the Army APH-5 Crash Protective Helmet was done with procedures and equipment specified by ASA Z24.22 - 1957. The results show that the APH-5 offers high attenuation at test frequencies 3,000 through 8,000 Hz. However, the APH-5 has relatively low sound attenuation between 75 and 2,000 Hz. In view of the poor sound attenuation characteristics of the APH-5, it has been recommended that the present earmuffs be replaced with high efficiency ear protective muffs. If changing earmuffs is not feasible, it is recommended that the APH-5 be replaced by a helmet with high sound attenuation characteristics.

APPROVED: Robert W. Bailey
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LTC, MSC
Commanding

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SOUND ATTENUATION CHARACTERISTICS OF THE ARMY APH-5 HELMET

INTRODUCTION

Acoustic noise is a problematic by-product of modern technology. It has been observed that with advances in aircraft and rocket engine power there is always an accompanying increase in acoustic power output. With present techniques of noise abatement there is little hope of changing these trends or reducing present high acoustic output of military aircraft without affecting payload or performance characteristics. Some change of internal noise spectrum may be accomplished by closing doors and by providing limited amounts of light acoustic treatment material. However, the overall sound pressure level is not expected to be changed significantly.

The high sound pressure levels in and around Army aircraft during operation may be considered a health hazard. The manifestation of various degrees of high frequency hearing loss among Army aviation personnel and the large sums paid by the Veterans Administration for hearing loss compensation bring attention to the fact that there is need for efficient ear protective devices.

The Department of the Army Technical Bulletin TB Med 251, 25 January 1965, recommends the initiation of a hearing conservation program for personnel who are exposed to relatively steady broad-band noise in excess of 92 db sound pressure level (re 0.0002 dyne/cm^2) in the octave-band 150 - 300 Hz and 85 db sound pressure level in the five octave-bands between 300 Hz and 9600 Hz. Sound analyses have shown that the sound pressure levels in most Army aircraft are usually much greater than the TB Med 251 criterion for the initiation of a hearing conservation program.

The establishment of personnel protective measures is one essential provision of an effective hearing conservation program. Ear plugs are made available to Army aviation personnel as a principal protective measure against noise. They provide adequate protection for some personnel in some acoustical environments. However, ear plugs alone are inadequate, universally, for all personnel under all operational conditions. There is a need for more attenuation in extremely high sound pressure levels. Also, it is estimated that a large number of personnel avoid the use of ear plugs because of discomfort and other reasons. In view of the urgency of the need for protection against noise hazards and the inadequacy of the ear plugs as a universal protector, it is imperative that efficient sound attenuation characteristics be an integral part of the flight crash protective helmet.

The purpose of this report is to evaluate the real-ear sound attenuation characteristics of the Army APH-5 helmet with MX - 2088/U earphone cushions. Each earphone cushion is attached to a coiled spring which is fastened to the side of the helmet. The spring-loading of the earphone cushion provides a seal between cushions and head for various head sizes. See Figures 1 and 2.

PROCEDURE AND EQUIPMENT

The evaluation of the sound attenuating characteristics of the APH-5 helmet was accomplished with procedures, equipment and physical requirements specified in The Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold, ASA Z24.22 - 1957.

One additional low frequency test tone (75 Hz) was added to nine standard frequencies 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. The tones were generated by a Hewlett Packard 241A oscillator. See block diagram of instruments in Figure 3. The output of the oscillator was connected to a step attenuator set, a Hewlett Packard 350D with a range of 110 db in one db steps. This attenuator provided the experimenter with a calibrated control of test tone levels for checking subject's reliability; also, the control of over-all sound pressure levels of test tones was necessary for subjects with extremely low thresholds and for boosting levels when testing attenuating devices of high efficiency.

The output of the 350D attenuator was fed into a Grason Stadler 829D electronic switch. The electronic switch interrupted the test tones with a 50% duty cycle and with off and on durations of 500 msec. The rise and decay time of the switch was 50 msec. The signal from the electronic switch was amplified with a Hewlett Packard 467A power amplifier.

A Grason Stadler E3262A recording attenuator was inserted between the power amplifier and an Altec 605B loudspeaker. The recording attenuator was provided with control switches that may be operated by the subject and the experimenter. The subject's switch was a photoelectric clickless type. The experimenter's switch had facilities for changing directions, stopping the attenuator and overriding the subject's control. Having the recording attenuator on the output of the power amplifier provided attenuation of the test signal and amplifier noise. The voltage to the loudspeaker was measured by a Hewlett Packard 3400A RMS voltmeter. The circuit was calibrated with this

Figure 1. The Army APH-5 Crash Protective Helmet

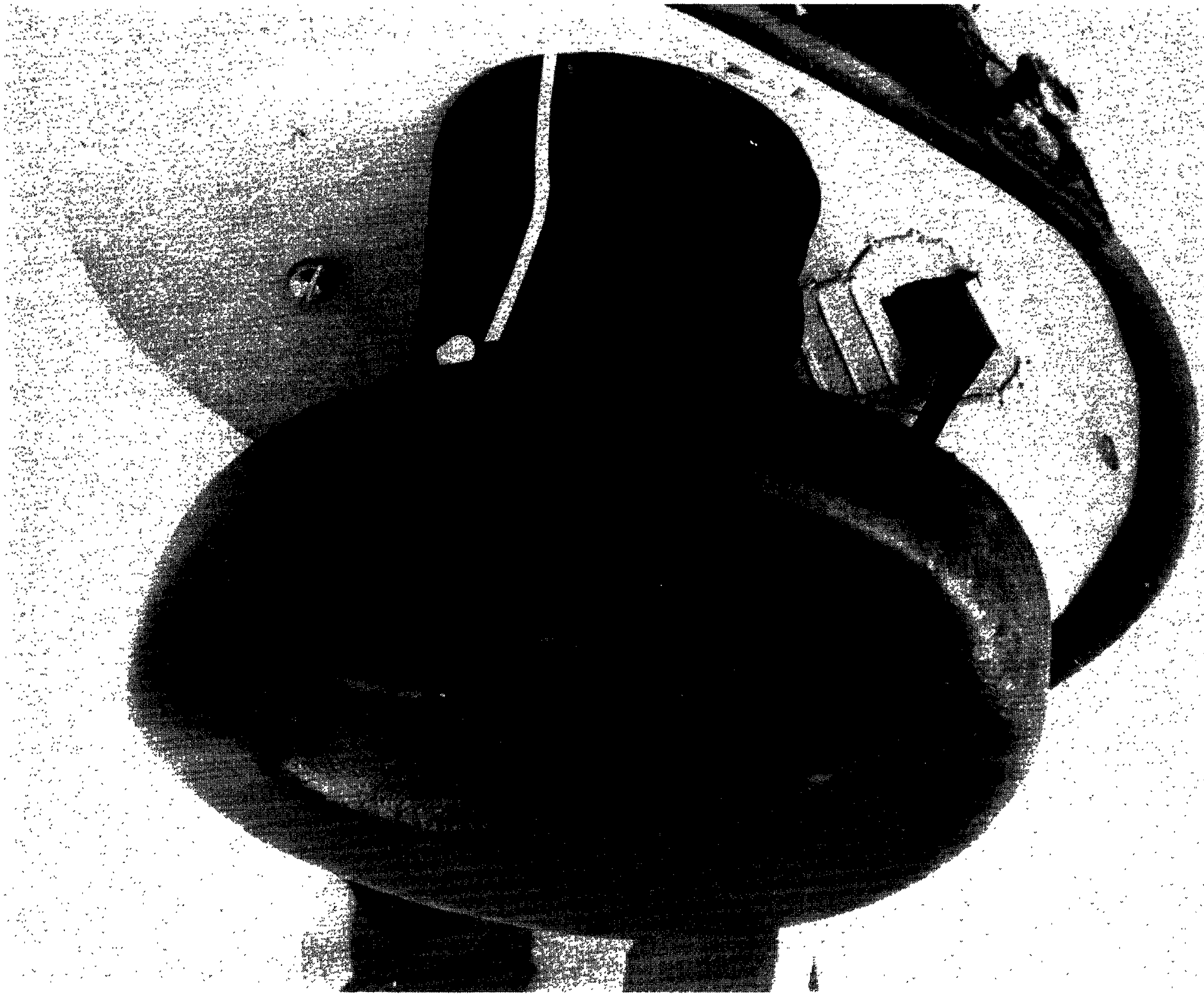
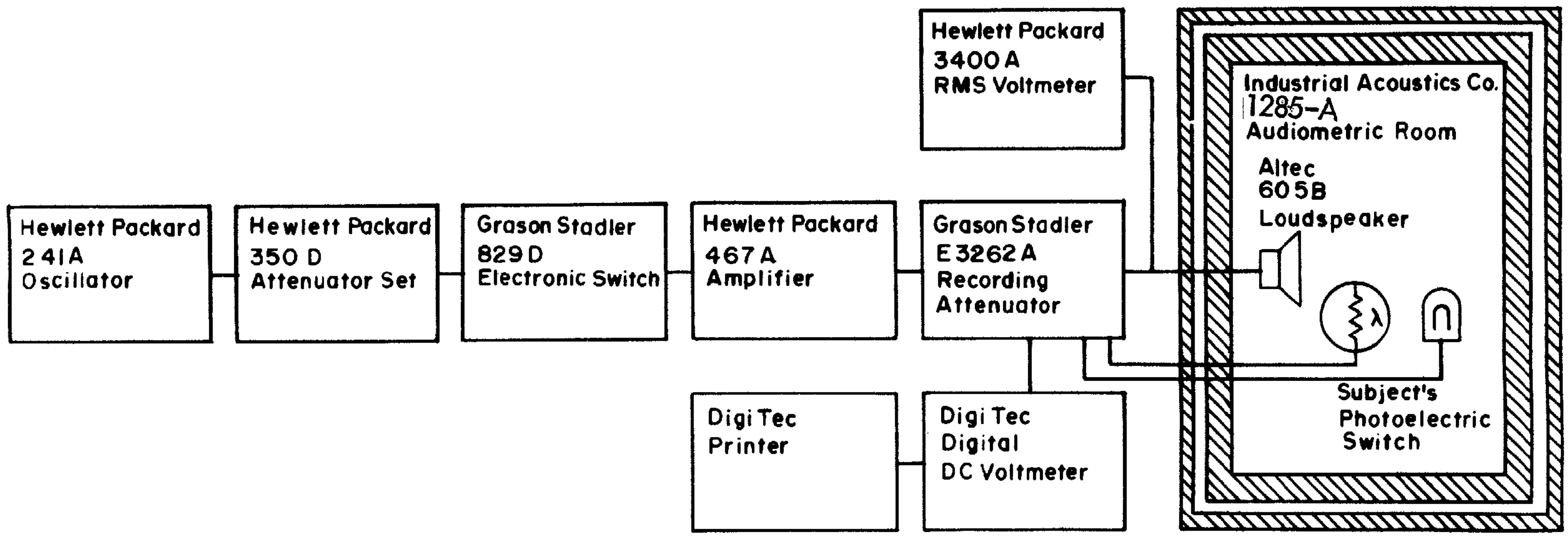


Figure 2. The Earphone Cushions in the Army APH-5 Crash Protective Helmet



BLOCK DIAGRAM OF INSTRUMENTATION FOR REAL-EAR ATTENUATION TEST

Figure 3

voltmeter at the beginning of each test.

In addition to the recorded information on the recording attenuator paper, there was digital print-out of the attenuation values. A potentiometer was coupled mechanically to the recording attenuator which controlled a DC voltage as a function of attenuator setting. The voltage across the potentiometer was adjusted to indicate 1.000 volt on a Digi Tec digital DC voltmeter when the recording attenuator was set at 100 db attenuation. By arbitrarily moving the decimal point, the voltage indication may be taken as a representation of the attenuation value of 100.0 db. The linear relationship between the change of attenuation of the recording attenuator and the accompanying voltage change across the potentiometer yields digital voltage readings that are numerically identical to attenuation values registered on the recording attenuator. This information was printed by a Digi Tec printer which was connected to the digital voltmeter. This arbitrary system of representing attenuation values with voltage readings had a resolution equivalent to one-tenth decibel.

The recording attenuator circuitry was provided with a one shot monostable multivibrator circuit that sent a print command each time the subject changed recording attenuator direction. With a Bekesy type response for constant test tones, there was an oscillation of attenuator values around the subject's threshold. This oscillation is due to the activation and release of the attenuator control switch when the listener perceives and ceases to perceive the acoustic stimuli, respectively. The print-out facility provided digital print-out of minimum and maximum values of the oscillations around the subject's threshold. The printer also provided a sum total of the response values at the command of the experimenter.

A quiet environment was provided by the Industrial Acoustics Company 1200A double wall audiometric room. The intensity gradients were measured for certain test tones as required by the ASA Z24.22 - 1957. Tables I through III contain sound pressure levels measured at one inch increments along three axes from the subject's head. These were the normal maximal sound pressure values of each test tone after calibration. This particular 1285-A has extremely high attenuation characteristics throughout the audio spectrum because of special construction and design features of the building in which it is housed. Table IV shows a one-third octave-band statistical analysis of the room noise. The system noise of the instrumentation used to measure the room noise is also shown. The noise measurement instrumentation was a calibrated one-inch Brüel & Kjaer microphone, a Brüel & Kjaer Audio Frequency Spectrometer Type 2112,

Table I

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values Are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz.	Distance in Inches Below the Normal Head Position						Normal Head Position	Distance in Inches Above the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	70.5	70.6	70.8	71.2	71.4	71.6	71.8	71.7	71.8	72.1	72.3	72.3	72.5
125	77.2	77.6	77.8	77.8	78.0	78.2	78.5	78.5	78.7	79.0	79.2	79.4	79.6
250	84.3	84.3	84.1	83.6	83.4	82.9	82.8	82.6	82.4	82.0	81.8	81.6	81.5
500	89.4	89.3	89.1	89.0	88.9	88.6	88.6	88.5	88.5	88.6	88.6	88.7	88.8
1000	84.9	84.8	84.6	84.4	85.2	85.6	86.2	86.2	86.0	85.7	85.4	84.7	84.3
2000	85.6	85.8	85.5	84.6	84.0	84.2	84.8	84.9	84.8	84.4	84.0	84.4	85.0
3000	83.8	83.4	85.6	86.2	85.4	83.4	85.0	86.6	87.3	85.8	84.8	85.0	85.2
4000	84.1	85.0	84.8	85.4	87.8	87.0	85.2	85.4	84.6	84.4	84.8	84.0	82.1
6000	72.6	71.7	72.8	77.8	80.5	84.2	82.0	82.0	80.6	76.4	78.1	77.2	77.3
8000	79.2	78.0	77.9	81.1	81.8	83.4	83.6	84.2	85.1	82.4	84.4	81.1	83.0

Table II

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz.	Distance in Inches in Front of the Normal Head Position						Normal Head Position	Distance in Inches Behind the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	76.7	76.1	75.4	74.6	73.9	73.3	72.2	71.4	70.7	70.0	69.2	68.6	68.3
125	81.1	80.6	80.4	80.0	79.6	79.2	78.6	78.4	78.1	77.8	77.2	77.4	76.6
250	80.8	81.5	82.8	81.9	82.6	82.8	83.0	83.2	83.5	83.6	83.7	83.7	83.6
500	87.2	87.8	88.0	88.4	88.5	88.5	88.2	88.1	87.9	87.6	87.3	86.7	86.6
1000	86.0	84.6	83.4	83.7	84.7	86.0	86.6	86.5	85.8	84.6	83.3	82.4	82.5
2000	83.4	84.2	86.7	85.7	81.8	82.9	85.3	84.0	80.0	82.0	84.2	83.4	81.3
3000	82.6	83.8	83.4	83.6	85.3	82.0	82.6	80.2	78.8	83.3	79.5	84.4	85.8
4000	84.9	85.7	85.5	85.3	85.8	84.3	84.5	82.6	85.0	84.1	83.0	83.2	81.2
6000	78.0	81.4	80.6	77.8	79.0	81.2	82.8	72.6	77.8	80.8	82.0	75.0	77.8
8000	79.6	78.6	82.6	82.0	82.0	82.7	82.4	80.1	80.6	80.2	82.1	79.8	80.6

Table III

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values Are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz.	Distance in Inches Left of the Normal Head Position						Normal Head Position	Distance in Inches Right of the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	71.6	71.6	71.7	71.7	72.1	72.0	72.3	72.3	72.3	72.4	72.4	72.5	72.3
125	78.1	78.2	78.3	78.4	78.6	78.5	78.6	78.8	78.9	78.9	79.0	79.0	79.0
250	82.4	82.5	82.6	82.7	82.8	82.8	82.9	83.0	83.1	83.1	83.1	83.1	83.2
500	88.2	88.5	88.7	88.9	89.0	88.9	88.9	88.6	88.4	87.9	87.5	87.0	86.4
1000	85.2	85.7	86.1	86.4	86.6	86.3	86.0	85.4	84.7	84.1	83.6	83.4	82.6
2000	83.0	83.2	83.7	84.5	84.7	84.9	85.2	85.1	85.1	84.7	83.3	82.6	84.4
3000	84.7	82.9	82.5	80.9	80.8	82.3	84.6	86.2	85.2	82.6	81.2	82.4	85.0
4000	82.4	82.0	82.4	81.6	82.4	82.8	83.8	84.6	82.6	80.5	82.3	84.3	82.5
6000	82.5	81.3	82.5	82.5	77.1	73.4	82.0	81.7	74.4	79.5	83.0	78.1	84.8
8000	76.4	81.7	79.1	81.7	83.6	83.1	83.1	84.7	79.9	83.7	76.2	81.5	74.2

Table IV

Mean Sound Pressure Level and Standard Deviation Values in Decibels (re 0.0002 Dyne/cm^2) of Ambient Acoustic Noise in the Industrial Acoustics Company 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. Also Shown are System Noise Data of the Instrumentation Used in Measuring the Acoustic Noise.

One-Third Octave-Band Center Frequencies in Hertz	System Noise		Room Noise	
	Mean SPL Equiv.	Standard Deviation	Mean SPL	Standard Deviation
25	18.13	3.15	29.36	2.97
31.5	16.13	2.80	28.68	3.07
40	16.00	2.90	29.48	2.95
50	14.76	2.42	30.36	2.55
63	15.83	2.12	31.97	1.52
80	12.87	2.17	14.36	1.95
100	11.38	1.70	16.81	0.37
125	9.70	1.75	28.93	0.85
160	9.32	1.50	9.88	1.25
200	8.02	1.42	10.99	1.22
250	6.14	1.25	17.81	1.22
310	5.58	1.32	11.56	0.67
400	4.86	1.17	14.21	0.32
500	4.18	0.82	4.58	0.95
630	2.65	1.22	4.46	0.80
800	2.08	0.90	4.55	0.90
1,000	1.59	0.60	2.40	1.12
1,250	2.68	1.20	4.17	0.65
1,600	1.26	1.00	3.22	1.22
2,000	0.96	1.22	2.18	0.95
2,500	0.31	1.27	1.78	0.27
3,150	0.73	1.22	8.97	0.80
4,000	0.58	1.25	4.16	0.47
5,000	1.46	0.80	2.53	1.15
6,300	1.75	0	2.98	1.15
8,000	2.35	1.07	1.90	0.60
10,000	1.75	0	4.30	1.72
12,500	2.49	1.15	4.25	0
16,000	4.25	0	4.26	0.15
20,000	4.25	0	4.62	0.87
A	36.75	0	36.75	0
B	34.25	0	35.65	1.25
C	46.75	0	49.32	0.70
Lin	56.75	0	56.75	0

a Brüel & Kjaer Level Recorder Type 2305, and a Brüel & Kjaer Statistical Distribution Analyzer Type 4420. The system noise measurements were done with the microphone cartridge replaced by a 50 pico farad capacitor.

RESULTS AND DISCUSSION

The mean real-ear attenuation and standard deviation values in decibels are shown in Table V. The same data are depicted graphically in Figure 4. In terms of absolute attenuation values, it may be seen that the APH-5 yields high attenuation values at test frequencies 3,000, 4,000, 6,000 and 8,000 Hz. There was a moderate amount of 29 db at 2,000 Hz. The attenuation obtained at 75, 125 and 1,000 Hz may be considered to be low. For the remaining test tones of 250 and 500 Hz, the respective values of 6 and 7 db are considered to be extremely low.

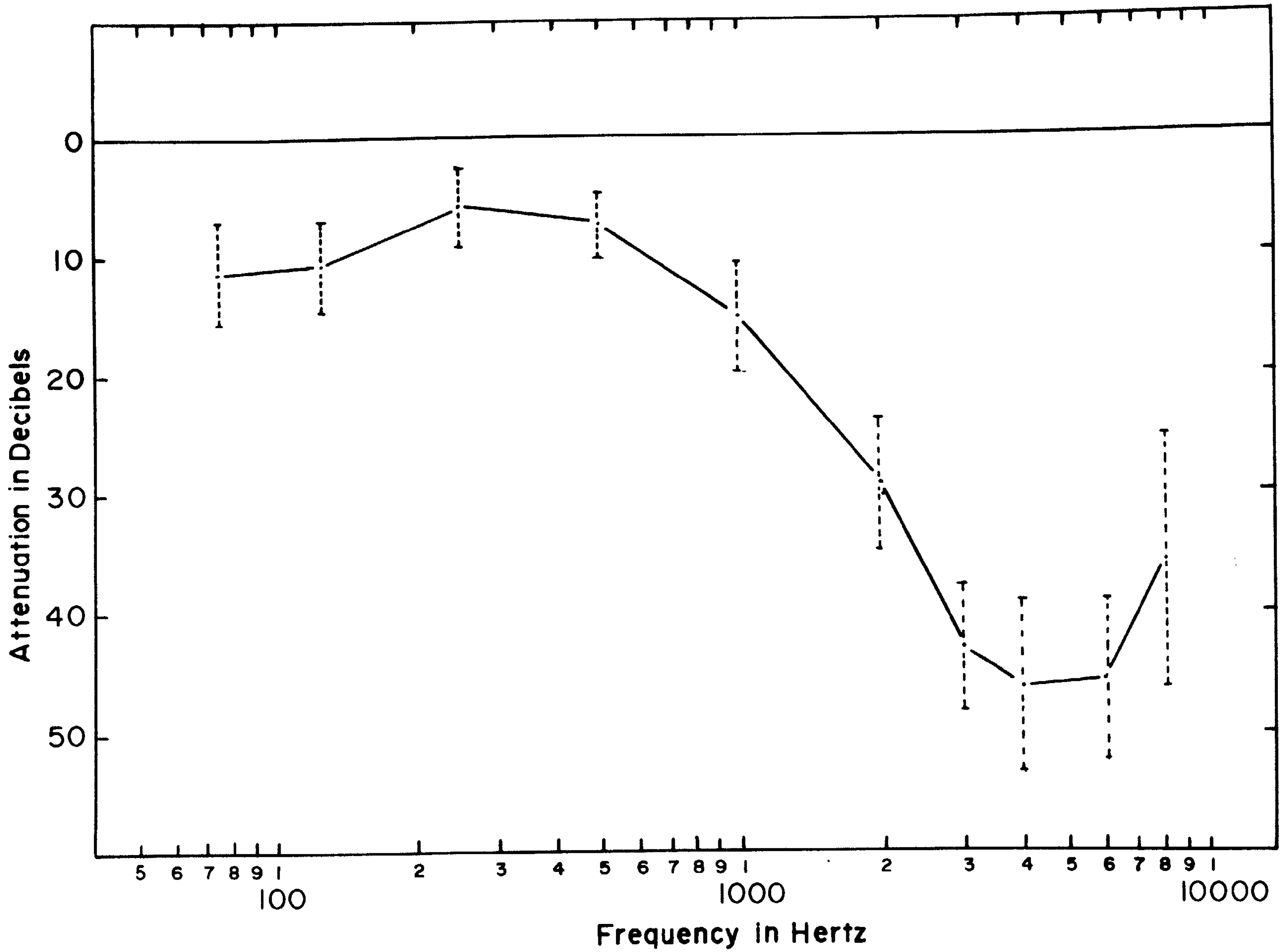
It is difficult to evaluate the attenuating efficiency of an ear protector by absolute attenuation values alone. One cannot assess the significance of a value without some knowledge of the inherent limitations for each test frequency. For example, a value of 18 db may mean very high attenuation at certain low frequencies and relatively a poor attenuation at some high frequencies. USAARU Report No. 66-6 on The Real-Ear Sound Attenuation Characteristics of Thirty-Six Ear Protective Devices gives a recapitulation of attenuation values provided by existing devices. Tables VI and VII are from this report. Table VI shows the upper limits for eight test frequencies. It may be seen that the range of the upper limits is from 20 to 50 db. Table VII contains decile values in decibels for mean real-ear attenuation data of thirty-six ear protective devices. It is believed that a meaningful assessment of the relative attenuation efficiency of the APH-5 may be determined by the transformation of the absolute values into decile rank values.

Figure 5 shows a curve representing decile ranks of the attenuation values with respect to thirty-six other attenuating devices. This curve reflects the relative efficiency of the APH-5. The curve shows that, starting with 75 Hz there is a decile rank near 6 with a declining decile rank with frequencies 125, 250 and 500 Hz. The curve also shows that the helmet is least efficient at 500 Hz. There is an increase of efficiency between 500 and 4,000 Hz which had a decile rank of 9. The relative efficiency dropped to near a decile rank of 7 at 8,000 Hz. The relative comparison of the APH-5 with other attenuating devices shows, in other words, that the efficiency is low between 75 and 2,000 Hz. Between these frequencies the decile ranks were near 6 or less. The relative efficiency at 250, 500 and 1,000 Hz, which were all below a decile rank of 4, is considered to be extremely low.

Table V

Mean Real-Ear Sound Attenuation
and Standard Deviation Values Obtained with the
Army APH-5 Helmet

Test Frequencies in Hertz	Mean Attenuation Values in Decibels	Standard Deviation in Decibels
75	11.34	5.03
125	10.86	4.55
250	5.98	4.15
500	7.11	3.52
1000	15.37	4.84
2000	29.11	5.61
3000	43.00	5.26
4000	46.26	7.07
6000	45.83	6.92
8000	35.97	10.83



REAL-EAR SOUND ATTENUATION CHARACTERISTICS OF AN APH-5 HELMET

Figure 4

Table VI

Minimum, Median, Maximum, Mean, and Standard Deviation in Decibels of Real-Ear Attenuation Values Obtained from 36 Ear Protective Devices

	75 Hz*	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Minimum	1	- 1	- 1	2	1	3	14	14
Median	9	9	9	16	22	26	35	32
Maximum	20	20	28	36	41	38	50	41
Mean	10.1	9.5	10.7	17.5	22.3	26.5	34.2	31.8
Standard Deviation	5.48	6.53	7.73	10.19	10.18	8.62	7.0	5.93

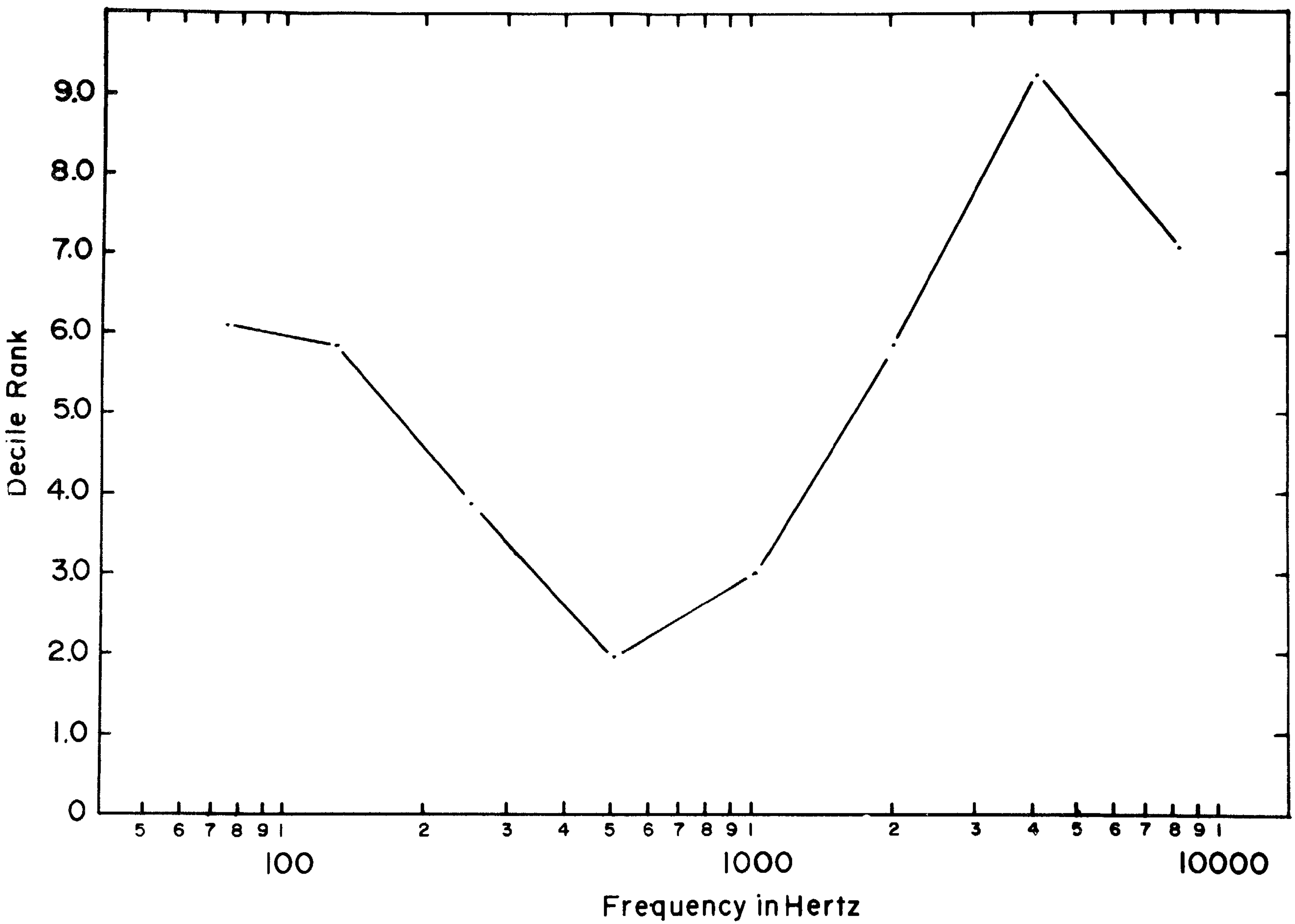
*Computed from data of 34 ear protective devices.

Table VII

Decile Values in Decibels for Mean Real-Ear
Attenuation Data of 36 Ear Protective Devices

Deciles	75 Hz*	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
D_1	2.3	0.3	0.0	3.8	2.4	15.8	27.8	24.8
D_2	4.1	2.9	3.1	7.1	11.7	19.1	29.6	26.6
D_3	5.9	4.4	4.4	10.3	15.4	21.3	31.3	28.4
D_4	7.3	6.9	6.2	13.7	18.9	25.6	32.9	30.2
D_5	9.5	9.0	9.5	16.5	22.0	26.5	34.7	32.5
D_6	10.9	11.1	13.7	18.8	25.8	29.3	35.8	34.0
D_7	13.9	14.1	15.6	24.7	30.2	32.7	37.6	35.9
D_8	15.2	15.4	18.3	29.3	32.3	34.8	38.4	37.4
D_9	17.1	18.7	20.9	30.3	35.6	36.7	41.9	38.3

*Computed from data of 34 ear protective devices.



Decile Ranks of Real-Ear Attenuation
Values Obtained with an APH-5 Helmet
Figure 5

The results of the real-ear attenuation test on the APH-5 show that the APH-5 does attenuate adequately at 2,000 Hz and above. Its performance in the low end of the audio spectrum is considered to be poor.

The spring-loaded earmuff provides what is considered to be adequate universal fitting for earmuffs. The lack of attenuation of the APH-5 is, therefore, not a matter of proper seal. The material and design of the ear cups are considered to be the primary cause of the poor attenuation characteristics of this helmet.

CONCLUSION AND RECOMMENDATIONS

A standard ASA Z24.22 - 1957 real-ear attenuation test was performed on the Army APH-5 helmet. A total of ten listeners, tested three times each, served as subjects. This is the minimum number of subjects specified by ASA Z24.22 - 1957 for an acceptable test. The mean attenuation values derived from these tests have shown that the APH-5 does attenuate adequately between 4,000 and 8,000 Hz. At test frequencies below these values, the attenuation is considered to be from poor to very poor. The region of 250 and 500 Hz, where the least amount of attenuation was obtained, is considered to be critical for communication purposes.